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CIRCULAR NO. 189

TWENTY-FIVE YEARS OF ENGINEERING GEOLOGY IN ILLINOIS

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REPRINTED FROM THE TRANSACTIONS OF THE ILLINOIS STATE ACADEMY OF SCIENCE
VOL. 46, pp. 7-16, 1953

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

URBANA, ILLINOIS
1954

(90129)

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Illinois Academy of Science Transactions, Vol. 46, 1953

PRESIDENTIAL ADDRESS

TWENTY-FIVE YEARS OF ENGINEERING GEOLOGY IN ILLINOIS*

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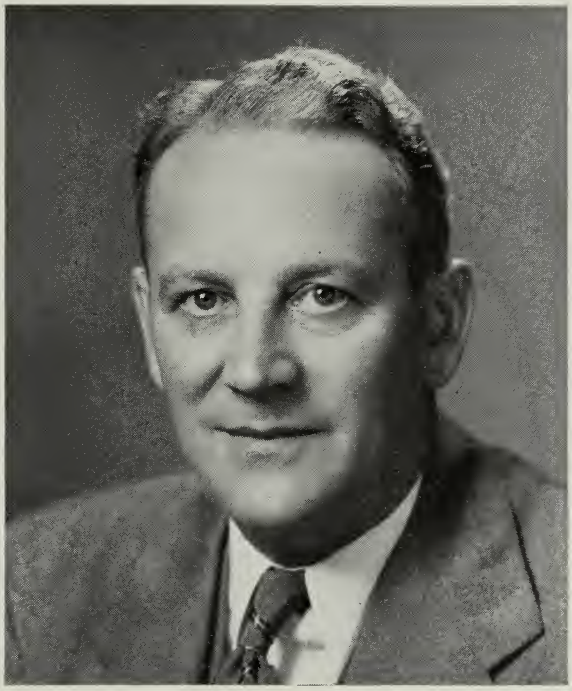

GEORGE E. EKBLAW, *President,* 1952-1953

On July 1, 1927, slightly more than 25 years ago, engineering geology as a distinct branch of science was first formally recognized in Illinois by the establishment of a Division of Engineering Geology of the State Geological Survey. This action developed from the work which Dr. M. M. Leighton, Chief of the Survey, had been doing for the State Highway Division for several years. It was my good fortune at that time to have been asked by him to take charge of the work of the new division. After a couple of years I was assigned the position and title of Head of the Division, a position I have had ever since.

* The presidential address as presented was accompanied by numerous lantern slides which are not herewith reproduced because of the cost.

Engineering geology as such has of course been practiced for generations—in fact, William Smith of England, who is recognized as one of the earliest stratigraphic geologists, actually was an engineer who developed that branch of science as a means of guiding him in excavation work. But in 1927 it had not been generally recognized as an independent branch of geology, and the attitude of geologists toward it was perhaps betrayed by the fact that as I engaged upon my duties my colleagues dubbed me "landslide geologist"—they might really have meant "backslide geologist."

In 1927 the number of men who admittedly practiced engineering geology could probably be counted on the fingers of two hands. Among them were such men as Berkey, Terzaghi, Wentworth, and a few others. Since then the number has increased to scores, possibly a few hundred. A separate Engineering Geology Section of the Geological Society of America was inaugurated about five years ago, and separate programs of the Section are held at each annual meeting of the Society. Engineering geology is being subdivided into special fields, such as geology of highway engineering, and programs in the separate fields are presented at various places in the country, in some cases annually, in some cases sporadically.

So far as is known, the Engineering Geology Division of the Illinois State Geological Survey was the first formal organization in that branch of science—no other nation or state in the world is recorded as having one as late as 1939.[1] Since then the U. S. Geological Survey, the U. S. Reclamation Bureau, the U. S. Corps of Engineers, other Federal agencies, many state geological surveys in this country, and many foreign national and provincial governments have established engineering geology organizations. I confess to feeling a considerable degree of pride in having been one of the early workers in this field that has developed so rapidly in 25 years.

[1] Legget, Robert M., Geology and Engineering, p. 613, footnote. New York and London, 1939.

Certainly one factor, and probably a second which has developed simultaneously, has contributed to the rapid growth of engineering geology. The first of these is the science of soil mechanics. This branch of civil engineering projects towards geology just as engineering geology projects towards engineering—they comprise a pair of links that closely couple their two parent fields. Soil mechanics, as it is now recognized, was also in its infancy in the 1920's. Professor Karl Terzaghi, whom we regard as the founder of the science, or at least of its current manifestation, was just then beginning to publish the results of his investigations and his concepts. Since then soil mechanics, like engineering geology, has developed phenomenally, so that in this country and abroad there are scores of engineers specializing in it, every engineering college of any repute has a curriculum or a department of soil mechanics, laboratories have been established, many textbooks and reference books have been written, and the field is constantly expanding.

The second possible factor is a concomitant development in soil science. Also in the 1920's Dr. C. F. Marbut of the U. S. Department of Agriculture introduced into this country the Russian Glinka's concept of the soil profile, or the weathering profile, which was rapidly accepted by all scientists working with soils. For geologists and engineers it provided a guide to the recognition of significantly different zones of weathered earth materials.

In the middle 1920's the State Highway Division was completing two large bond-issue programs of paved-highway construction in the State. Along the first highways constructed, landslides, pavement settling, excessive cracking, heaving, disruption by frost, and other troublesome phenomena were occurring. When planning and constructing the highways, the engineers had not been aware of unfavorable geological conditions and their implications.

It is therefore not surprising that in the beginning most of my endeavors in engineering geology were concerned with highway problems. For 8 or 9 years about 85 percent of the engineering problems I studied were related to highways. These comprised investigations of the geologic causes of landslides, pavement heaves, and excessive settlement of fills, examination of materials in limestone quarries and sand and gravel pits to ascertain what materials were present that were deleterious in pavement and bridges built with aggregates from such sources, studies of the reaction of materials in peat bogs to accelerate stabilization of fills across them, studies of drainage conditions under highways, especially in subways and at grade separations, studies of the foundations for bridges and subway and grade separation structures, recommendations for location of borrow pits, and participation in the selection of one of several alternative highway routes which would involve the fewest or least geologic problems. In later years studies of the subgrades of proposed new highways became the most prevalent problem of highway engineering geology.

Beginning in 1935-36, problems of highway engineering constituted a smaller proportion of the engineering geology problems in which I engaged. This was partly because from our mutual studies in the earlier years the highway engineers had learned to recognize and to avoid or to treat satisfactorily those geologic situations that create difficulties. Asked if I wasn't afraid of putting myself out of a job, I replied that if I couldn't find other avenues for my efforts but had to keep the engineers in ignorance of geology in order to preserve my job, I didn't deserve the job in the first place.

Although highway problems were less numerous, those I investigated were more interesting, larger in scope, and involved more difficult situations. Landslides persisted as the largest single group of problems, but the study of subgrades became more pronounced and was a close second.

Beginning in 1936, there developed in Illinois a tremendous interest in water-supply reservoirs and recreational lakes, which has continued with the result that studies of geologic conditions at proposed damsites have constituted more than half of our endeavors since that time. Interest in reservoirs and damsites was first whetted by the Federal Public Works Administration program of aid for municipal improvements, including better water supplies. Under this program, many municipalities too small to afford the cost of constructing water-supply reservoirs and treatment plants were able to proceed with such improvements. Warned by the collapse of the Wyandot dam in Kansas, which had been constructed under P.W.A. auspices, the P.W.A. engineers in Illinois became more cautious, and once they learned that our services were available, no dam on the P.W.A. program was approved for construction without our consultation, advice, and recommendations.

In 1945 the State Department of Conservation initiated their recreational lakes program, with the objective of constructing at least one recreational lake in each county of the State. The resulting demand for geological investigation of the proposed damsites has required most of our attention. When this program was terminated in 1949 because of the large state appropriations that obviously would be necessary to carry it out, the interest it had engendered continued. Many local organizations and groups of citizens interested in recreational activities requiring or centering in lakes were encouraged by the State Department of Conservation to sponsor the construction of such lakes. Consequently the study of damsites continues as the dominant part of our engineering geology services. The new projects of the program of recreational lakes sponsored by the State Department of Conservation, in which a large share of the funds needed for their construction is the State's allotment from the Federal excise tax on sport-fishing equipment as provided by the Dingell-Johnson bill, are included in these studies.

There is insufficient time for a discussion of all phases of engineering geology studies which we have pursued and of the geologic principles involved. Because our activities in highway engineering lend themselves best to illustration, I shall restrict discussion to this field.

Reduced to the simplest terms, most of the problems of highway engineering geology may be ascribed to excess water. Excess water contributes to landslides of all kinds, sod-creep, sloughing of cut banks, pavement heave, frost disruption, and, of course, drainage problems. Other factors also play their part, but I estimate that if we could in some miraculous way dispose of excess water under or beside our highways, we would reduce by at least 90 percent the troubles engendered by geologic conditions.

The fundamental conditions for a potential landslide are (1) the contact of two materials, one more pervious than the other, (2) water in excess of an amount the materials can absorb, and (3) an exterior slope steeper than that of equilibrium. The most favorable conditions are, in addition, (4) that the more pervious material lies above the less pervious, and (5) that the contact between them slopes downward towards the exterior slope. However, they will also occur even when the more pervious material lies under the less pervious or when the contact is flat or even sloping upward towards the exterior slope, provided the weight of the material subject to movement is sufficient. Also, landslides or rockfalls may occur in a single material when, in the presence of excessive water or excessively steep exterior slope, the lateral component of the force from the weight of material exceeds its internal cohesion.

Under any of these conditions, whether created naturally or artificially, landslides may and do occur. Throughout Illinois they are abundant along valleys and artificial cuts, especially in deep railway and highway cuts. A typical landslide, naturally created, was encountered along the northeast side of LaMoine River northeast of Ripley in Schuyler County, in the course of a survey for the location of what is now State Highway No. 103. Here glacial till with a layer of gravel at its base lies essentially horizontally on bedrock shale. Erosion by a meander of the river at the toe of the slope oversteepened it beyond the angle of equilibrium for the material. A mass of the till extending several yards up the slope broke away and moved down and out into the river. The trees on the lower part of the slide leaned downward and outward; on the upper part they leaned backward, revealing the rotatory motion of the slide. The rupture at the upper edge of the slide created a crevasse and a vertical wall several feet high. Without the support of the material moved in the first slide, material higher in the slope then moved in a second slide, that still higher in a third slide. Surface water running into the crevasses aggravated the condition and encouraged further movement, which will continue until the entire slope is reduced once again to the angle of equilibrium. It is hardly necessary to add that when the situation was explained to the engineers, they changed the contemplated routing of the highway to avoid the landslide.

All too frequently the equilibrium of an established slope has been disturbed by making a highway cut across it, and if the conditions potential for a landslide are present, the consequence is not at all in doubt. I am glad to say that over the years I have been able to provide the highway engineers of Illinois with information which has enabled them to route many of our new highways so that they avoid most of the potential landslides.

Because in Illinois we have relatively few steep rock cliffs, rockfalls comparable to landslides do not frequently occur, but in one instance a serious rockfall of this type was narrowly averted. Along the Palisades north of Savanna, where Silurian limestone in vertical cliffs about 200 feet high lies on Maquoketa shale, the original talus at the foot of the cliffs was removed in the course of widening the highway. The removal of the talus permitted the shale to squeeze out from under the limestone, thus letting masses of the limestone settle and fall away from the rest. Fortunately, the undesirable possibilities of this situation were promptly recognized and were forestalled by replacing the talus at the foot of the cliffs. The details of this problem were discussed in a paper presented in the Geology Section of this Academy several years ago.[2]

Landslides where the less pervious material overlies more pervious material are much less frequent. A

[2] Ekblaw, George E., Cause and prevention of potential rockfalls north of Savanna: Trans. Ill. Acad. of Science, vol. 22, pp. 450-454, 1930.

typical one occurred along the highway in Starved Rock Park, at a place where Pennsylvanian shale overlies St. Peter sandstone. The highway was constructed on the shale, only a few feet above the sandstone. As the bottom of the shale was lubricated by the water along its contact with the sandstone, it slid out into the adjacent canyon, carrying the highway with it. Here the engineers fortunately could prevent further movement by constructing a retaining wall soundly footed in the sandstone.

Conditions contributing to landslides that will carry pavement away are not infrequently created when the highway is constructed with its inner part on the base of a cut in a slope and its outer part on fill built up on the slope. Where such construction cannot be avoided, the tendency for landslides can be greatly reduced by the installation of proper drains, especially on the upslope side of the highway, so that excess water can be intercepted and carried away.

Similarly, conditions favorable for landslides are created when the toe of a talus slope is transected for a highway. Because talus has no inherent cohesion, it tends to move as soon as its slope of equilibrium is disturbed. An example of this occurred in Bartonville, south of Peoria, where the downslope movement of talus that had been transected for a highway eventually destroyed several houses.[3] If a talus slope must be transected to accommodate a highway, its surface should be reduced far back, so that the new slope approximates the original.

[3] Ekblaw, George E., Landslides near Peoria: Trans. Ill. Acad. of Science, vol. 24, pp. 350-353, 1931.

A different and possibly unexpected reaction that sometimes develops when a talus slope is transected is that the pavement is heaved up. This occurs when the highway is constructed on or over a relatively soft shale formation that extends under an adjoining slope. The weight of the material in the slope over the shale tends to push it out laterally; the removal of the talus for the highway provides an avenue for the shale that is being pressed out laterally to move upward. Before its removal the talus was counterbalanced against such movement. This is one problem for which there is no solution unless it is possible to remove an appreciable amount of the material in the slope that is weighing down on the shale.

Earlier I referred to the weathering profile of soils. The topmost, usually humic, layer of a soil profile is commonly silty and porous whereas the next underlying layer is clayey and dense, usually more clayey than lower layers, because during weathering some of the clayey minerals and material from the topmost layer is transferred to the second layer. This phenomenon, especially where it is well developed, is important in engineering geology. First, the difference in texture may be so great that the two layers react differently beneath a highway, either where they are in place or where they may be segregated in a fill. Second, surface water soaks readily down through the topmost layer but is checked at the second layer. Where there is a slope this water naturally tends to flow down on top of the second layer, which becomes a lubricated surface down which the overlying layer slides. This gives rise to the process known as sod-creep, whose effect can be perceived on any fairly steep slope. It is one process by which valley slopes are reduced. In highway construction sod-creep, induced or accelerated by the transection of grassed slopes, becomes a pernicious nuisance at least, because it seemingly continues interminably and often extends from the highway far up slopes in adjacent private property.

The downslope flow of surface water at the contact between the topmost and second layer of a soil profile provides additional trouble for the highway engineers. When this water comes to the brink of a cut in a slope, it runs down the face of the cut. If the material in the cut is at all silty or soft, it sloughs off and the face of the cut recedes, with concomitant troubles. Under certain conditions, the material may become actually fluid and flow out on the pavement or fill the ditches and disrupt the drainage along the highway.

It has been found that these undesirable effects can be satisfactorily controlled, if not wholly prevented, by installing at the top of the cut as near to the brow as practical a drain that will intercept the water and carry it down the sides of the slope to points of discharge where it can do no damage. These drains are installed in trenches that are backfilled with porous material to insure interception of the water; the material excavated from the trenches is cast on the downslope side to form a barrier to surface flow and further to insure maximum interception.

One of the earliest applications of this type of drainage was the installation by the Cook County Department of Highways of an elaborate system of drains on the south slope of Mount Forest Island, along the north side of what is now State Highway No. 83.[4] Because the land was a heavily wooded tract belonging to the Cook County Forest Preserve, it was imperative that the sloughing and sod-creep that started immediately when cuts for the highway were made be positively checked. The drains served the purpose admirably and the $22,500 that they cost was considered money well spent.

In south-central Illinois, where the differentiation of the top two layers of the soil profile is most pronounced, the contact between them is evident wherever the highway crosses a valley of any size. On earth roads the contact is marked by deep mudholes in wet weather and consequent chuckholes in dry weather; on pavements the contact is always a zone of excessive seepage and potential pavement disruption. Cross-drains under the pavement and porous subbase are essential to correct the situation.

In the early years of our engineering geology work, peat bogs provided a frequent problem in highway engineering, especially in northeastern Illinois. Even where a paved highway followed what appeared to be a stable earth road across a bog, the fill for the pavement or the heavier traffic over it often was sufficient to cause settlement or collapse. Investigations revealed that in most instances the bogs were covered by a

[4] Ekblaw, George E., and Campbell, D. M., A noteworthy example of drainage to prevent landslides: Illinois Engineer, vol. VII, no. 8, p. 3 and 6, December 1931.

mat of peat underlain by muck. The muck was more or less fluid and had little or no bearing power, yet the peat mat apparently had sufficient tenacity, supplemented by the slight support afforded by the muck, to uphold the light horse-drawn traffic over the earth roads but not enough to support the paved roads and motor traffic.

Considerable difficulty was encountered in constructing across a bog a fill that would remain stable. A fill that at first appeared complete and satisfactory might subsequently settle or collapse. Several methods were tried and eventually a most effective one was devised. A fill was constructed across the bog as rapidly as possible, whose height was at least as great as the depth of the bog plus the desired height of pavement above the bog and whatever width was required to maintain the height. Then through the fill and down to the bottom of the bog, holes were drilled at predetermined intervals in 3 or 4 longitudinal lines parallel to the highway, one along each side and one or two in the center. Charges of explosives were set in the portions of the holes that were in the muck, and then detonated, the two outer lines momentarily ahead of the inner line or lines. It was reported that when this method was first put into practice, in a bog forty feet deep near Elgin, the fill rose en masse as the explosive was detonated and then settled down into the bog surprisingly close to the calculated grade for the highway.

Subsidence of fills in other incompetent mucky areas is not uncommon. Usually there is lateral movement away from as well as lowering under the fill. A typical example of this phenomenon occurred a few years ago when the heavy fill for the new route of State Highway No. 13 southeast of East St. Louis was built across the Mississippi River bottoms. Again explosives were used to accelerate settlement of the fill, and the material that was moved laterally away was salvaged by large draglines that pulled it back into place.

More recently, during the construction of a fill for the new route of U. S. Highway No. 40 across Little Creek east of Marshall, in Clark County, where test borings had indicated that laminated clay underlay the stream alluvium, the weight of the fill caused the clay to yield. As a result, heaves occurred along the south side of the fill, the side of the fill moved downward and outward much like a landslide, the south wing-walls of the concrete box-culvert were pulled away, and the south section of the box-culvert was separated from the north section. A reduction in the height of the fill served apparently to check the movement.

Unfortunately there is insufficient time to discuss in a similar manner all the other types of geologic problems in highway engineering or the problems involved in our studies of damsites. However, I cannot pass this opportunity to remark the admirable procedure which the State Department of Conservation adopted for the investigation of damsites for their program of recreational lakes. Suggestions for possible damsites were universally solicited, and literally hundreds of sites were proposed. The engineers of the Department investigated the sites and if it was decided that they merited further study, fundamental data, including area and volume of the proposed lake, drainage area, run-off, possible pollution, percentages of wooded pasture and cultivated land, distance from population centers, and so forth, were compiled. These preliminary engineering reports were submitted to several agencies, among which were the State Geological Survey, the State Natural History Survey, the State Water Survey, the Soil Conservation Service, the State Waterways Division, and the several Divisions of the Department of Conservation itself. If any of these agencies for some reason considered a proposed site unfavorable, it was eliminated from further consideration.

Damsites approved tentatively by all agencies were then surveyed by the Department of Conservation engineers. The resulting preliminary plans for the proposed damsites were submitted to us to determine where test-borings should be made. We studied the samples from the test-borings and interpreted the geologic conditions, all before the final design of the dam was drafted. Thus all possible precautions were taken to insure a safe, satisfactory dam.

Our work with highways and dams has been emphasized, but there has been also a host of miscellaneous problems, some of which have been very important. These include studies of subsidence over mined-out areas, among which the study of an area in southeast Springfield several years ago and of the Peoria airport recently are outstanding, sewer excavations, park sites, river locks, pollution problems, drainage problems, foundations of buildings and structures, and many others. Of these miscellaneous problems those of drainage and foundations are most numerous.

There is no time to discuss all of these, but you may be interested in one which I regard as the most unusual I have encountered in my engineering geology experience. On my return to the office after a day in the field a few years ago, I found that I had been committed to an immediate investigation of an explosion of a grave in a cemetery at a nearby town. When I arrived at the town, I learned that the burial was 40 to 50 years old and was in an underground concrete vault that had been built around the casket. I also learned that as news of the explosion had spread about, so many people had come to see it that the cemetery officials had put a fence around the lot. After being assured that the officials of the cemetery and relatives of the deceased sanctioned excavation of the grave, we proceeded to the cemetery. It was immediately apparent from the assemblage already present and steadily increasing that my expected arrival had not passed unnoted or unheralded.

I think you can imagine my feelings, as, totally ignorant of what we should discover, it was necessary that I proceed to direct operations for the investgation before the eyes of such a crowd, who I felt were undoubtedly almost as curious to see how the "expert" would conduct his investigation and how he would arrive at a decision as to see what would be discovered. After definitely eliminating all possibility of any human participation in the event, our ultimate interpretation was that gas leaking from the supply main that ran underground not too far from the cemetery had followed tile drains into the cemetery, had accumulated in the burial vault, and had been ignited by a thunderbolt. In support of this interpretation were the facts that (1) there had been a thunderstorm in the vicinity during the 2-3 days that had elapsed between the day the caretaker had mowed the grass in the lot and the day he noted the disturbance of the grave, (2) a lady living near the cemetery reported that during the storm she had heard a detonation which she could hardly believe was ordinary thunder, and (3) a week or so later newspapers reported two incidents elsewhere in the country where thunderbolts had detonated accidental accumulations of gas in underground chambers under construction.

This demonstrates the range and variety of the work of an engineering geologist in a single state. Each day holds the possibility of something new and different. Less than a year and a half ago a new field of study—the excavation of subterranean chambers for storage of liquid gases—opened up and since then has occupied much of our time. We regard the past with considerable gratification and we await the future with equal anticipation.